Multi-sources data analysis with sympatho-vagal balance estimation toward early bruxism episodes detection.

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***Abstract*— Sleep bruxism events detection system is presented, based on integrated, synchronized on-line analysis of EMG signal, heart rave variability (HRV) obtained from ECG recordings as well as sympatho-vagal balance estimated in real time as an possible early indicator of upcoming bruxism episodes. As an relative reliable alternative for very complex systems, only for clinical environment usage with audio and video recordings a pilot study toward elaboration of compact, comfortable for home usage device with early bruxism detection algorithms was carried out, preliminary tested on 10h sleeping registrations from group of 12 patients, clinically characterized by experts as Bruxers. As a result a set of decision rules regarding simultaneous monotonic increase of heart rate with significant increase of EMG signal amplitude during bruxism episode was elaborated. But a most promising observation, which can be useful for earlier prediction of upcoming bruxism episode seems to be a monotonic increase of LF/HF ratio in HRV power spectrum components, expressing sympatho-vagal balance of autonomous nervous system, which according to our assumptions take basic low level role in bruxism phenomena trigger and control.**

I. Introduction

Sleep bruxism (SB) affecting about 8% of adult population [1] is relatively common and destructive clinical ailment, with still not well known knowledge about reasons and mechanisms of its generation and triggering. While it is known to be associated with transient lightening of the sleep state, the underlying aetological trigger is not well understood [2]. In severe cases, or cases that are poorly managed over time, bruxism can cause considerable damage to teeth and restorations. It can be defined as sleep-related movement pathology of masticatory system characterized by grinding and clenching of the teeth during sleep. It is characterized by phasic and/or tonic contractions of the masseter and other jaw muscles. Main bruxism clinical features, which are harmful both for teeth and implants are:

- temporo-mandibular joint pain and discomfort.
- mobility of teeth.
- tenderness and hypertrophy of masticatory muscle.
- muscle pain when patient wakes up in the morning.
- muscle activity becomes abnormal and also interfere with temporomandibular joint (TMJ) functions

The most common management of bruxism is based on minimizing the abrasion of tooth surfaces by the wearing of a bite-guard, or splint in the mouth [3,4]. Currently, there is no definitive method for assessing bruxism clinically that has reasonable diagnostic and technical validity. There are also no reliable, easy to use, long-term continuous monitoring devices for bruxism detection and prevention, available commercially.

Difficulty of bruxism diagnosis results mainly from the fact that similar noticeable symptoms can have different reasons, e.g. not all contractions of masticatory muscles during sleeping are bruxism episodes or heart rate fluctuations can be caused by various sources. Taking into consideration this complicated problem structure the aim of presented work was to carry out a pilot study toward multi-source data approach elaboration for more reliable bruxism detection. Presented hybrid methodology focuses mainly on non-invasive way acquired ECG and HRV signal analysis both in time and frequency domain but as a reference signal for future verification usage a one of the direct method of bite force sensing system is considered.

The occurrence of sleep bruxism can be identified during awake and sleep stages by using multiple physiological measurements supplemented with audio and video recordings while clinical investigation in special prepared sleeping rooms [5]. Diagram showing integrated sources of data presented in literature for bruxism episodes detection and analysis is presented in fig.1

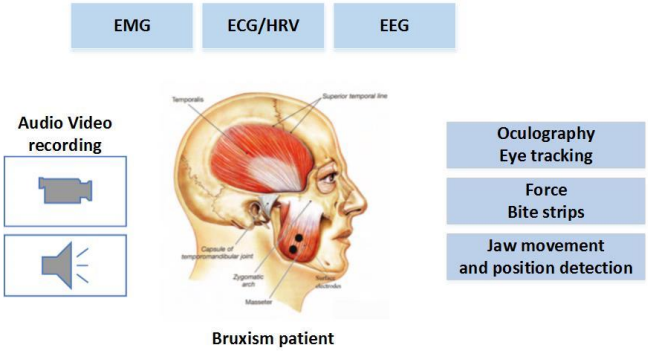

Fig.1. Different data sources and signals used for bruxism detection.

A major disadvantage of this whole equipment is the high cost, its complexity and their usage mainly in laboratory settings, thus providing information of oral behaviors that may not be representative for patients in the natural environment (e.g. at home) [6].

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The goal of presented work was to select a crucial signal(s), recording in non-invasive way in relative comfortable conditions and methodology, able to detect bruxism on reliable level not only in clinical/laboratory conditions but available to be implemented in compact device, comfortable for patient also at home. A integrated, synchronized on-line analysis of EMG signal, heart rave variability (HRV) obtained from ECG recordings as well as sympatho-vagal balance estimated in real time as an possible early indicator of upcoming bruxism episode was carried out for 10h sleeping registrations from group of 12 patients, clinically characterized by experts as Bruxers.

The idea of presented project started from our assumptions, resulting after many years of research in the field of HRV reflection of autonomous nervous system control, that sympatho-vagal balance, which can be estimated by spectrum analysis of HRV, take basic low level role in bruxism phenomena trigger and control.

II. METHODOLOGY

A hardware layer of data acquisition system consist of standard 7-lead holter for recordings with sampling frequency Fs=500 [Hz] of: ECG, EMG from masseter muscle and electro-oculography signal taken from electrodes placed on patient's temples on the eye line (see fig.2).

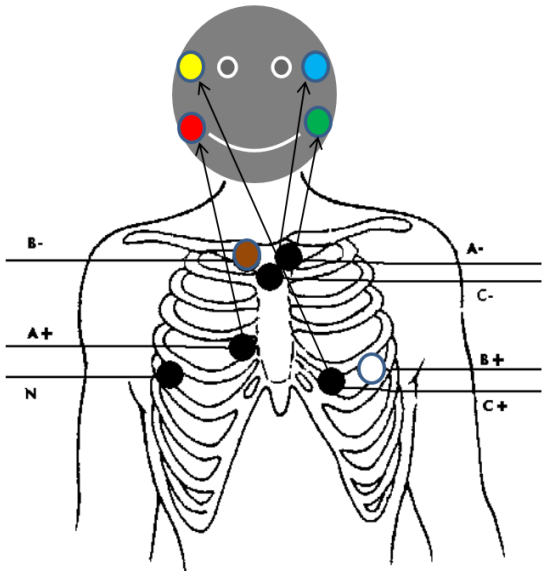

Fig.2 Holter electrodes placement for EMG, ECG & EOcu recordings.

The most crucial part of presented project as common in medical diagnosis support system is feature extraction and selection stage, where from many input redundant signal properties (in this case – samples of recorded signals), new measures are computed, which are most suitable to the problem.

Raw ECG, EMG and Electro-Oculography (EOcu) signals were processed according do diagram presented in fig.3 to finally obtain significant features, optimal for bruxism episode detection on the possible earliest phase.

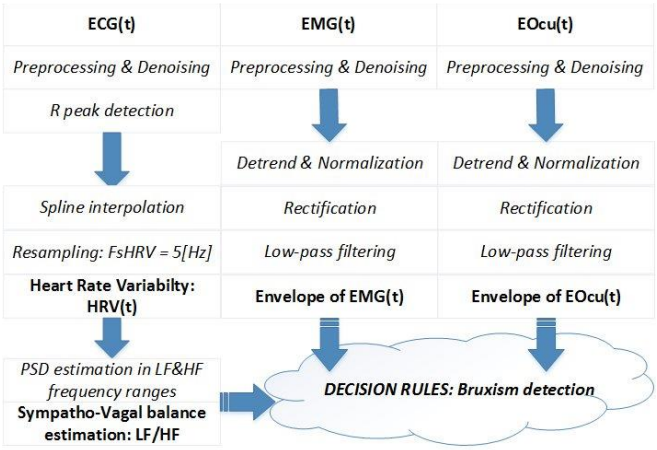

Fig.3 General structure of proposed bruxism detection support system based on ECG, EMG and EOcu raw signal processing & feature extraction

A. ECG signal processing

A signal processing procedure was carried out to determine crucial for bruxism detection heart rate variability (HRV) signal in following steps:

- ECG recordings with Fs=500[Hz], base-line drift removing by high pass filtering and denoising by low pass filtering
- R-detection algorithm based on Pan-Tomkins solution with adaptive threshold and extended decision rules set
- Spline interpolation of unevenly spaced, original R-samples and resampling with F_{SHRV}=5Hz.

B. Heart Rate Variability (HRV) analysis

Heart rate variability (HRV) analysis, is a well-known technique, that relies on the assessment of fluctuations on the intervals among successive ECG R waves and can be used as a powerful relatively easy accessible tool for the assessment of cardiac autonomic control.

The power spectrum density (PSD) of HRV signals from our database of bruxism cases was estimated for later comparison by means of representative of two main group of methods:

- Welch PSD (average modified periodogram), where the signal is splited into *L*-data segments of length *M* [7] as a non-parametric method.
- Yule Walker method based on auto-regressive data model, belonging to parametric type approach, which due to not suffering on leakage effects of windows can achieve better resolution than non-parametric methods.

Power [ms^2] in two frequency bands, under the estimated hrv spectrum were determined: low-frequency (LF: 0.2–0.8 Hz), and high-frequency (HF: 0.8–2.5 Hz) and a ratio LF/HF were computed as a main indicator of sympathovagal balance, computed on-line before and during bruxism episodes.

It is common known, that the powers of the LF and HF oscillations characterizing heart rate variability (HRV) appear to reflect, in their reciprocal relationship, changes in the state of the sympathovagal balance occurring during numerous physiological and pathophysiological conditions.

C. EMG and EOcu signal processing

The goal of EMG and EOcu signal processing was to estimate the envelope of theses signal. Applied procedure can be divided in following steps:

- EMG signal detrending and normalization to remove DC offset
- Rectification before low-pass filtering is crucial getting the shape or "envelope" of the EMG signal, because the nature of EMG signal, which consists of fast oscillations near zero, hard to smooth in natural form.
- Low pass filtering of rectified signal with 10Hz cut off frequency by means of 5-th order Butterworth IIR filter with Hamming window, applied in both the forward and backward directions, resulting in zero phase shift.

III. RESULTS

A tested group of signal consisting of 10h long sleeping registrations from group of 12 patients in home environment, clinically characterized by experts as Bruxers.

A. Synchronized patterns analysis

As a result of signal processing stage, described above, carried out on raw input data a synchronized set of 180s long signals of HRV(t), EMG(t) with envelope and EOcu(t) signal with envelope was computed for different cases. A typical patterns for sleeping bruxism episodes is presented in fig.4, where simultaneous monotonic significant increase of heart rate (HR) and EMG as well EOcu lasting relatively long period of 15-20[s] can be observed.

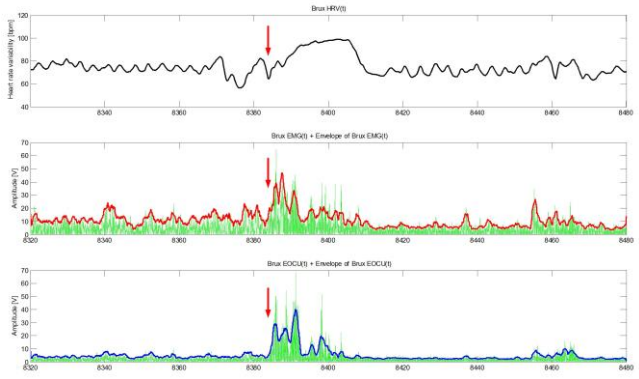

Figure 4. Example of typical bruxism pattern, 180s long, synchronized signals of HRV(t), EMG(t) with envelope (red) and EOcu(t) with envelope (blue) for bruxism episode marked.

An interesting case with multiple, consecutive SB episodes with 30-50 [s] interval is presented in fig.5, with similar to previous characteristic patterns and duration of mentioned waves.

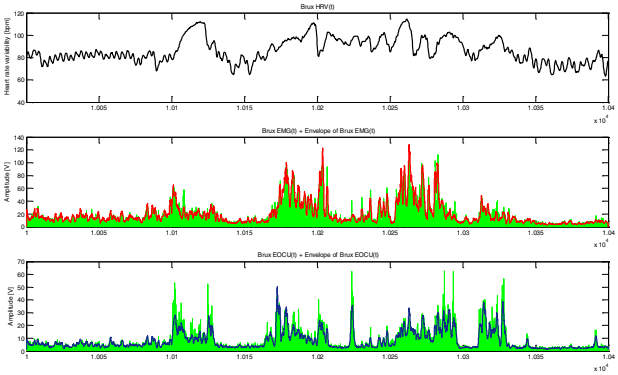

Figure 5. Example of multiple sleep bruxism episodes separated by 30-50[s] intervals with typical pattern for SB.

Presented in fig.6 set of patterns for non-bruxism recordings shows, that in SB detection not only increase of EMG amplitude, but its duration is the most important factors determining SB episodes. Here, too short duration of sudden amplitude growth does not correspond to bruxism episode.

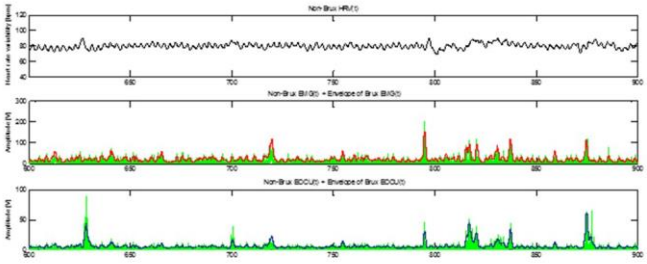

Figure 6. Signal patterns for Non-Brux case. An amplitude sudden growth can be seen but too short and with no monotonic increase of HR signal.

B. Heart rate spectral parameters analysis

A ratio of power of low (LF) and high (HF) heart rate spectral component LF/HF, which is know as indicator of sympatho-vagal balance in organism were computed in case of non-bruxism patterns and as a function of time, before observed SB episode. Mean value of this parameter is presented in Table 1. A significant increase of its value can be observed in time directly before SB occurrence.

TABLE I. MEAN VALUE OF HR SPECTRAL LF/HF RATIO BEFORE SB EVENT

LF/HF	**Time [min] before SB episodes**			
	NonSB level	***2 [min]***	***1 [min]***	***0[min] (SB)***
Mean	0.62	1.67	2.22	3.46

IV. CONCLUSION

Presented results of proposed system for detection of sleep bruxism (SB) episodes can be divided into two groups. Based on analysis of patterns, computed as a result of signal processing and feature extraction stage a decision rules, characterizing SB occurrence can be defined:

- SB event reveals during 10-20[s] long sudden amplitude increase of EMG and EOcu (>= 40% of base line
- synchronously Heart Rate monotonically increases from 20-40% of its mean value from last 10minutes

While mentioned observation allow to verify and confirm SB events during or at the beginning of its occurrence second group important results, connected with HR spectral LF/HF component ratio, reflecting sympatho-vagal balance can give a hope to be a reliable indicator of on-coming SB episodes. Value of this parameter known, as a good parameter of many hidden for direct measure in central nervous system regulations as can be seen in table 1 increase in several minutes before SB occurrence.

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